PROBING GLUON POLARIZATION WITH π^0'S IN LONGITUDINALLY POLARIZED PROTON COLLISIONS AT THE RHIC-PHENIX EXPERIMENT.

Y. FUKAO FOR THE PHENIX COLLABORATION

Kyoto University, Kyoto 606-8394, Japan
E-mail: fukao@nh.scphys.kyoto-u.ac.jp

This report presents double helicity asymmetry in inclusive π^0 production in polarized proton-proton collisions at a center-of-mass energy ($\sqrt{s}$) of 200 GeV. The data were collected with the PHENIX detector at the Relativistic Heavy Ion Collider (RHIC) during the 2004 run. The data are compared to a next-to-leading order perturbative quantum chromodynamic (NLO pQCD) calculation.

1. Introduction

Polarized lepton-nucleon deep inelastic scattering (DIS) experiments over the past 20 years revealed that only ~25% of the proton spin is carried by the quark spin. Therefore the gluon spin and orbital angular momentum must contribute to the rest of the proton spin. In polarized proton-proton collisions one can explore the gluon polarization directly using the processes that gluons participate in. One of the promising probes is to measure the double longitudinal spin asymmetry (A_{LL}) in high p_T particle production.

The first measurement of A_{LL} in π^0 production at RHIC during the 2003 run (run-3) has been published[1]. Present report shows the latest results of π^0 A_{LL} for the range of 1–5 GeV/c in transverse momenta (p_T) and from -0.35 to 0.35 in pseudorapidity (η) obtained during the 2004 run (run-4).

A_{LL} is defined by the following formula.

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}, \tag{1}$$

where σ is the cross section of the process in interest, $++$ ($+-$) denotes that the variable is obtained in the collisions with same (opposite) helicity beams. Taking into account the beam polarizations and the luminosity variations between the two possible spin orientations, equation 1 becomes,

$$A_{LL} = \frac{1}{|P_{B_1}||P_{B_2}|}\frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}, \qquad R = \frac{L_{++}}{L_{+-}}, \tag{2}$$

where P_{B_1} and P_{B_2} are the beam polarizations. N is the yield (of π^0 in this report), L is the integrated luminosity and R is what we call the relative luminosity. These $P_{B_1(B_2)}$, N, and R were measured in the experiment.

2. Experimental setup

RHIC was operated with both proton beams polarized longitudinally at $\sqrt{s}$ =200 GeV. The machine performance in run-4 is compared to run-3 briefly in Table 1. For the double helicity asymmetry, the statistical figure of merit is expressed by $P_{B_1}^2 P_{B_2}^2 L$. In spite of the short run period in run-4, the figure of merit is larger due to higher beam polarization.

Table 1. PHENIX data summary in run-3 and run-4.

	run period	L (nb^{-1})	$< P_B >$ (%)	figure of merit (nb^{-1})
run-3	4 weeks	220	27	1.17
run-4	4 days	75	40	1.92

The beam polarization was measured by the proton-Carbon CNI polarimeter[2] constructed near IP12, away from PHENIX, where the systematic error of the beam polarization was 32%. This affects the scaling error of the double helicity asymmetry by 65%.

Since the stable direction of the beam polarization is vertical in RHIC, we must rotate the beam polarization before and after the collision point to obtain longitudinal polarization. The PHENIX[a] local polarimeter[1] confirmed that the direction of the proton spin in the PHENIX collision point was more than 99% longitudinal.

The relative luminosity, R, was evaluated using the beam-beam counter and the zero-degree calorimeter in PHENIX to be $\delta R = 5.8 \times 10^{-4}$, which corresponds to $\delta A_{LL} = 1.8 \times 10^{-3}$ for a beam polarization of 40%.

3. π^0 A_{LL} results

In the analysis, we did not subtract the background under the π^0 peak directly. Instead, we calculated A_{LL} in the two-photon invariant-mass range of ± 25 MeV around the π^0 peak (A_{LL}^{raw}), we call this the "signal" region, then corrected it by A_{LL} of the background (A_{LL}^{BG}) to extract A_{LL} of pure π^0 ($A_{LL}^{\pi^0}$) using

$$A_{LL}^{\pi^0} = \frac{A_{LL}^{raw} - rA_{LL}^{BG}}{1-r}, \qquad \Delta A_{LL}^{\pi^0} = \frac{\sqrt{(\Delta A_{LL}^{raw})^2 + r^2(\Delta A_{LL}^{BG})^2}}{1-r}, \qquad (3)$$

where r is the fraction of the background in the "signal" range and is obtained by fitting. A_{LL} of the background is evaluated using the mass

[a] An overview of PHENIX is found in[3].

range near the π^0 peak. Table 2 shows the statistics of π^0's within "signal" mass window and the fraction of BG under the π^0 peak.

Table 2. The statistics of π^0s and the BG fraction.

p_T (GeV/c)	1-2	2-3	3-4	4-5
π^0 statistics ($\times 10^3$)	1151	510	91	17
BG fraction (%)	31	13	7	5

The systematic error of A_{LL} non-correlated between bunches or fills can be evaluated by the "bunch shuffling" technique.[1] We found such kind of systematics is negligible compared to the statistical error. The systematic error correlated over all bunches or all fills mainly comes from the uncertainty on the beam polarization and the relative luminosity described above.

Figure 1 and Table 3 show run-4 results of π^0 A_{LL} as well as that from run-3[1] and their combination with the statistical errors. Two theory curves[4] are also drawn in the figure. The confidence level between theory curves and our data combined for run-3 and run-4 was calculated to be 21-24% for the GRSV-standard model, 0.0-6% for the GRSV-maximum model, taking into account the polarization scale uncertainty. Our results favor the GRSV-standard model.

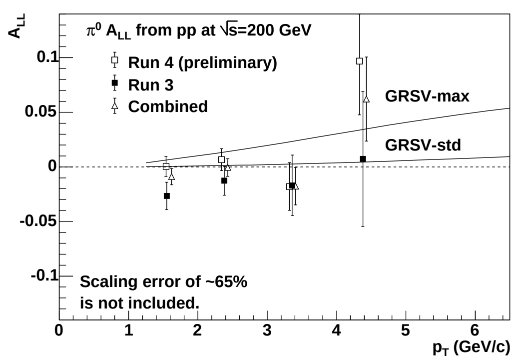

Figure 1. π^0 A_{LL} as a function of p_T.

Table 3. π^0 A_{LL} in run-4, run-3 and their combination.

p_T (GeV/c)	1-2	2-3	3-4	4-5
Run 4 (%)	0.0 ± 0.9	0.7 ± 1.0	-1.8 ± 2.2	9.7 ± 4.9
Run 3 (%)	-2.7 ± 1.3	-1.3 ± 1.3	-1.7 ± 2.8	0.7 ± 6.2
Comb. (%)	-0.9 ± 0.7	0.0 ± 0.8	-1.8 ± 1.7	6.2 ± 3.8

4. Future plan

RHIC plans to operate with higher luminosity and polarization in the future. Figure 2 shows the expected π^0 A_{LL} in run-5, where proton run

will start from February 2005, as well as in the next long pp run expected in 2006–7. The center value of those points follow the GRSV-standard. Three pQCD theory curves are also in the figure. Those are calculated with $\Delta g = +g$ (same as GRSV-max in Fig.1), $\Delta g = -g$ and $\Delta g = 0$ at the input scale ($Q^2 = 0.4$ GeV^2).[5] We can further constrain Δg in run-5. However, A_{LL} of π^0 can be approximated by the quadratic function of $\Delta g/g$ and it is hard to determine the sign of Δg only with low p_T data due to the duality of the quadratic function. One solution of this problem is to measure π^0 A_{LL} in the higher p_T region where the duality becomes less. (See run-7 estimation in Fig.2.) The other way is to combine results of π^0 with other channels, for example, A_{LL} of direct photons which is a powerful probe and will be measured in future runs with higher statistics.

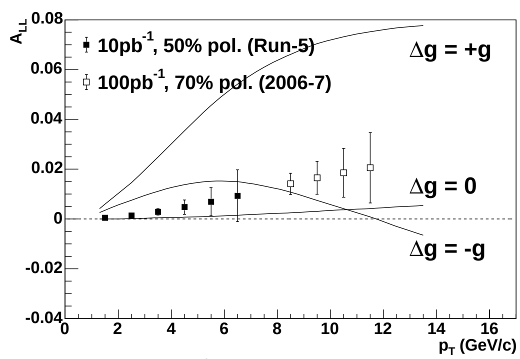

Figure 2. π^0 A_{LL} as a function of p_T.

5. Summary

We reported the results of A_{LL} in π^0 production in polarized proton-proton collisions at $\sqrt{s} = 200$ GeV measured in 2004 with the PHENIX detector at RHIC. π^0 A_{LL} was presented for 1–5 GeV/c in p_T and $|\eta| < 0.35$. The data was compared to NLO pQCD calculations and favors the GRSV-standard model on the gluon polarization. The expectation in the future runs was also disscussed.

References

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